BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 09017

SUBJECT: Modularized Nuclear Stage Performance for 1981 Mars 80-Day Stopover Mission Case 103-8

DATE: September 9, 1969

FROM: D. J. Osias

[redacted]

ABSTRACT

Availability of a 50,000 lb earth to earth orbit shuttle with a 22 ft diameter payload volume still requires utilization of Saturn V capability for launch of large volume payloads such as nuclear stages. A nuclear rocket which can be assembled in orbit from modules compatible with the earth to earth orbit shuttle holds the possibility of launching manned interplanetary missions from earth without use of the Saturn V. In this memorandum vehicle and propellant weights are calculated for the 1981 80-day stopover mission with inbound Venus swingby using nuclear rockets assembled from small modules compatible with an ILRV. The same mission using 33 ft diameter propellant tanks can be accomplished with about 350k lbs less weight in low earth orbit (1.64M lbs using large stages). However, the cost of launching the extra weight must be weighed against Saturn V launch costs.

(NASA-CR-106865) MODULARIZED NUCLEAR STAGE PERFORMANCE FOR 1981 MARS 80-DAY STOPOVER MISSION CASE 103-8 (Bellcomm, Inc.) 10 p

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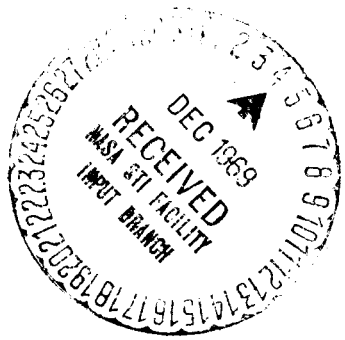

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MEMORANDUM FOR FILE

Availability of a 50,000 lb earth to earth orbit shuttle with a 22 ft diameter payload volume still requires utilization of Saturn V capability for launch of large volume payloads such as nuclear stages. A nuclear rocket which can be assembled in orbit from modules compatible with the earth to earth orbit shuttle holds the possibility of launching manned interplanetary missions from earth without use of the Saturn V. (1) However, a nuclear rocket assembled from small modules will be heavier for equal propellant quantities than one with a single, large propellant tank (launched by SV). Thus the issue addressed in this memorandum is whether this performance degradation seriously penalizes missions using space assembled nuclear rockets.

An analysis of the weights of the modularized nuclear vehicle and propellant for the 1981 80-day stopover Mars mission with inbound Venus swingby is presented here. The Mars vehicle uses only one Nerva I engine (75,000 lb thrust, 850 seconds Isp). To reduce gravity losses this vehicle should be boosted to either a highly elliptical earth orbit (HEO) or to trans-Mars injection (TMI) by additional engines. (The mission profiles are depicted in Figure 1 from Reference 2.) In the present analyses, two nuclear "shuttles" are used to boost the interplanetary vehicle from a 262 nm circular orbit to either HEO or TMI. The nuclear shuttles are assumed to be the same type of modularized vehicle as the interplanetary vehicle (one Nerva I each), and are capable of reuse if returned to earth orbit. They are also suitable for earth orbit-lunar orbit ferry operations. The Mars vehicle mentioned in Table I is defined as the nuclear rocket, spacecraft, and payload which performs the mission after separation from the nuclear shuttles.

The modules in this memo are sized to fit inside an earth shuttle with a cargo volume of 22 ft Dia x 60 ft L. and with a payload capacity of 50,000 lbs. Figure 2 shows an assembled interplanetary rocket. Each tank module holds 72k lbs of useable liquid hydrogen propellant. The engine module contains the engine and a small propellant tank with a capacity of 11k lbs. The empty

vehicle weighs 38,000 lbs plus 18,000 lbs times the number of tank modules; four, five, and six tank vehicles (excluding the small tank) have dry weights of 110k, 128k, and 146k lbs, respectively. (3)

The velocity requirements for the 1981 80-day stopover mission are as follows:

	Ideal* ΔV	Hybolic Excess Vel. in emos
262 nm circ to 24 hr ellipse (262 nm perigee)	8880	----
24 hr ellipse at earth to Trans-Mars injection	3350	.1184
Capture at Mars into 13.5 hr ellipse	5400	.1263
Escape from Mars 13.5 hr ellipse	13000	.2318
Earth capture into 48 hr ellipse (chemical propulsion: LM-B as described in Ref. 4)	4200	.1612

Table I presents the weights in low earth orbit (WILEO) and the total weight of propellant for a few mission profiles. The weights reaching the 24 hour elliptical orbit (WIHEO) are also given. All missions start in a 262 nm circular orbit with no refueling. For some missions the shuttles are returned to LEO and in others the shuttles are not recovered. In the latter case, the shuttles are really just expendable nuclear booster rockets. In the missions in which tanks are jettisoned, jettisoning takes place during coasting or orbiting periods between maneuvers, at which time all empty tanks are jettisoned. The calculated weights reflect off-loaded tanks carrying only enough propellant to perform the mission.

Gravity losses and after-cooling of nuclear engines which are to be reused are included. However, the velocity requirements for return of the nuclear shuttles from TMI to HEO were taken to be the same as the corresponding escape maneuver. Although this is not exact, the mission weights are still approximately correct.

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*In the calculations gravity losses are added to the ideal ΔV's to obtain the actual velocity requirements.

The payload (from Reference 2) for all missions is as follows:

		Wt.
Payload entering earth orbit upon return:	Mission Module	50k
	Crew Rescue Module	5k
	Empty Propulsion Module (LM-B)	10k
Additional payload leaving Mars:	Extra Mission Module	50k
	LM-B propellant (incl. maneuvering)	25k
	Venus probes	10k
Additional payload arriving Mars:	MEM + Hangar	85k
	Retrieval facility	15k
	6 MSSR's	50k
	LM-B maneuvering propellant	7.5k
Additional payload leaving Earth:	LM-B maneuvering propellant	7.5k

The lightest mission considered requires 1.53M lbs in low earth orbit and uses 12 tank modules, none of which is recovered; the shuttles, or boosters are abandoned in space and some modules of the Mars vehicle are jettisoned enroute.

The operationally simplest mission (i.e., no module jettisoning or return from TMI) is probably that in which two 5 tank shuttles boost a 7 tank Mars vehicle to HEO and then return to LEO. The 7 tank Mars vehicle then can complete the mission without jettisoning tanks. The total WILEO is 1.98M lbs and the total propellant is 1.22M lbs.

The mission using two 5 tank shuttles to boost a 7 tank Mars vehicle to HEO can be compared with a similar mission using larger 33 ft diameter tanks. The 33 ft vehicle is still modularized in that all tanks are the same size but the degree of modularity is different. The capacity of each tank is taken as 250k lb which is close to ideal for the particular mission under consideration. Therefore the weights for the mission using large tank vehicles are optimistic since in reality the

tanks would be sized for use in a variety of missions. The weight in low earth orbit using 4 identical 33 ft diameter tanks (one for each shuttle, 2 for the Mars vehicle) with a capacity of 250k lbs each is 1.64M lbs and the total propellant required is 973k lbs. Each tank weighs 50k lbs empty (λ = .83) and each tank plus engine module weighs 83.3k lbs (λ = .75). While the mission using the smaller modules (17 of them) requires significantly larger weights in orbit, comparisons for other mission profiles using the same modules could probably show smaller weight differences since the large modules are optimally sized for the particular mission considered here.

From the weight requirements listed in Table 1 for missions using small tanks, it can be noted that jettisoning tanks enroute saves roughly 60-250k lbs WILEO if reusable shuttles are employed. Returning the shuttles from TMI requires roughly 400-500k lbs extra WILEO.

In summary, the purpose of assembling nuclear stages from small modules is to reduce mission cost by elimination of Saturn V requirements. The cost of launching the extra WILEO by earth to earth orbit shuttle flights must be weighed against Saturn V launch costs.

D. J. Osias

1013-DJO-nma

Attachments
References
Figures 1 & 2
Table I

REFERENCES

1. Macchia, D., "Use of ILRV to Launch Large In-Space Stages," Letter to H. S. London, August 8, 1969.

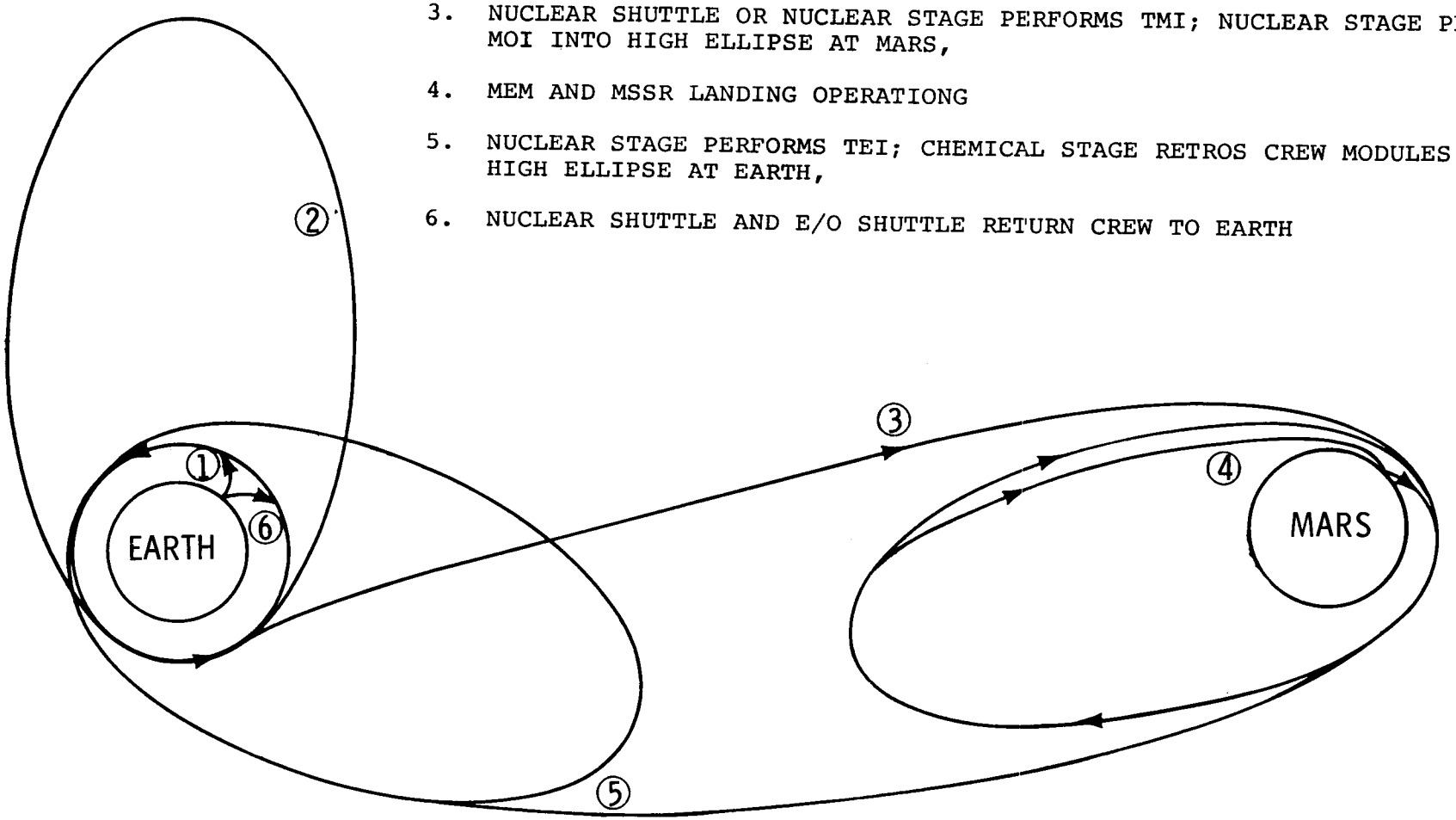
2. London, H. S., "Briefing on Manned Planetary Missions," Bellcomm Memo for File, July 30, 1969.

3. Kiersarsky, A. S. and Skeer, M. H., personal communication. Work will be published in future.

4. "An Integrated Program of Space Utilization and Exploration for the Decade 1970-1980," NASA, July 16, 1969.

FIGURE 1. PLANETARY MISSION - SYSTEM PROFILE

1. SYSTEM ELEMENTS PLACED AND ASSEMBLED IN LOW ORBIT WITH E/O SHUTTLE AND/OR SAT. V,
2. NUCLEAR SHUTTLE TRANSFER TO 24 HR ELLIPSE,
3. NUCLEAR SHUTTLE OR NUCLEAR STAGE PERFORMS TMI; NUCLEAR STAGE PERFORMS MOI INTO HIGH ELLIPSE AT MARS,
4. MEM AND MSSR LANDING OPERATIONG
5. NUCLEAR STAGE PERFORMS TEI; CHEMICAL STAGE RETROS CREW MODULES INTO HIGH ELLIPSE AT EARTH,
6. NUCLEAR SHUTTLE AND E/O SHUTTLE RETURN CREW TO EARTH



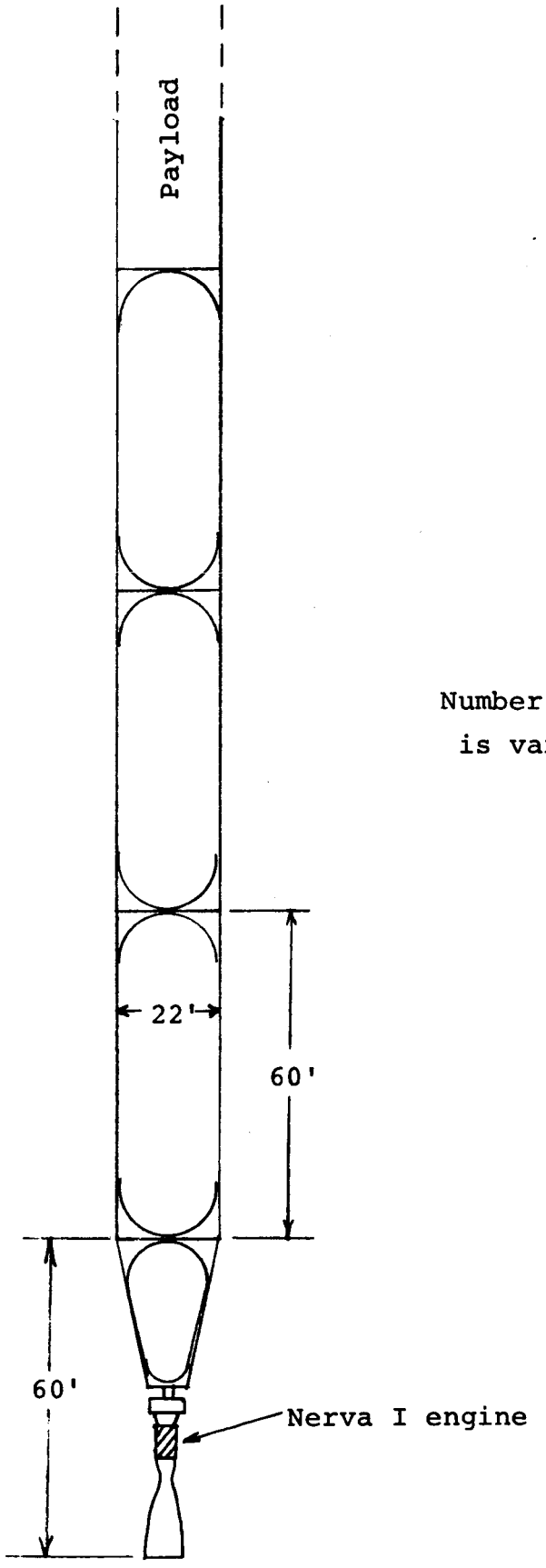


Figure 2. Modular Nuclear Rocket

TABLE I: 1981 80-DAY STOPOVER

Mission Description	WILEO(k)	Total Prop(k)	WIHEO(k)	Mars Vehicle Weight
No tanks jettisoned				
7 tank vehicle starting in 24 hr orbit (HEO)				
with shuttle boost from LEO to HEO, no shuttle return (two 4 tank shuttles)	1741k	1042	1197	977k
with shuttle boost from LEO to HEO, shuttles return (two 5 tank shuttles)	1977.5	1220.5	1355	977
5 tank vehicle starts from TMI				
shuttles boost from LEO to TMI, no return (two 5 tank shuttles)	1720	1020.5	1184	780
shuttles boost from LEO to TMI, return to LEO (two 7 tank shuttles)*	2135	1364	1421	780
Tanks jettisioned enroute to and at Mars				
6 tank vehicle in 24 hr orbit				
Two shuttles boost to HEO, and return to LEO (5 tank shuttles)	1720	1039	1181	801.7
4 tank vehicle starts after TMI				
shuttles boost from LEO to TMI, no return (two 4 tank shuttles)**	1530	895	1050	710
shuttles boost from LEO to TMI, return to LEO (two 7 tank shuttles)***	2076	1322	1423	710

*The two shuttles cannot return to LEO; upon reaching a 24 hr ellipse they have only 6,000 fps remaining instead of 9,000.

**12k prop. is transferred from Mars vehicle to shuttles.

***4k lbs prop. transferred from Mars vehicle to shuttles.

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